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(54) **Wireless indoor data relay system.**

(57) This invention removes the requirement of cable interconnection for local area networks (LANs) by wireless relay stations suitable for very high data rates by operation at high carrier frequencies where signal reflection and absorbtion by walls is total or requires undesirable high omnidirectional RF power transmissions. The LAN can be deployed without special installation requirements when operated with indoor transponders (U.S.Pat.4,975,926). In the preferred embodiment relay stations communicate with IR light beams, and wall and ceiling propagation blockage is overcome by low power RF structure couplers.

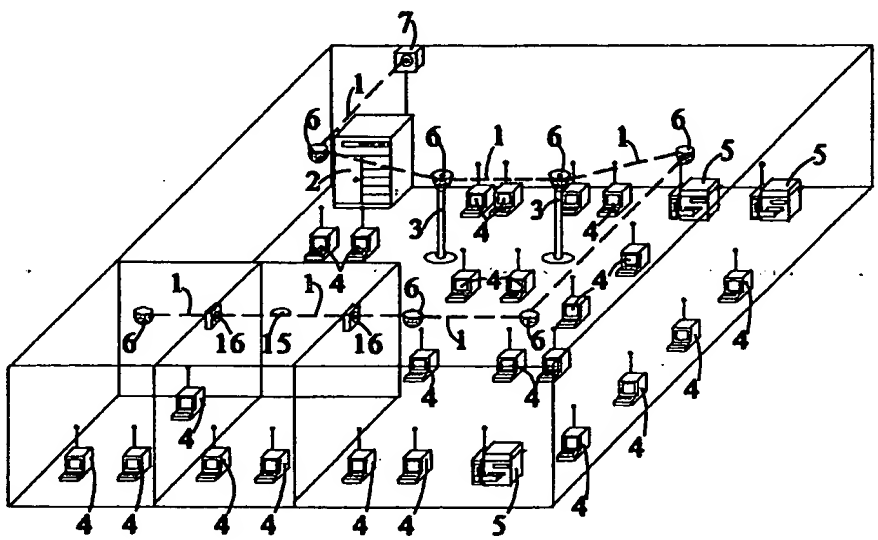

FIG. 1

EP 0 515 728 A2

Field of Invention

The present invention relates in general to communication systems and is particularly directed to improve practicality and utility of wireless indoor communication between workstations or other devices by means of infrared and other electromagmagnetic radiation over a local area network (LAN) or as a stand-alone system over a limited local area.

Description of Prior Art

U.S. Pat. No. 4,975,926 issued to G. Knapp on Dec.4, 1990 describes a wireless, high data rate, indoor communication system. The system discussed uses transponders for in line-of-sight communication to workstations. The transponders perform signal amplification, processing and distribution. All transponders are interconnected by cables.

The problem remaining in the prior art is to provide an optical or radio communication system which eliminates all cable connections and prevents signal blockage or severe attenuation by certain building structures, i.e. walls and ceilings, which is inherent to high electromagnetic carrier frequencies that are needed for accommodation of large signal bandwidths.

Summary of Invention

The foregoing problem in the prior art is solved to a large extent with the present invention by providing a tether-free operation for the transponders. More specifically, transponders are interconnected by radio waves and IR light beams throughout a building. The IR light beams are guided through unobstructed areas of ceilings, elevator shaft walls, staircase center spaces, skylight openings, etc.. Single or multiple beams form network data links to and from transponders equipped with network data link relay sections. Structure couplers extend, by low power radio wave coupling through non-metallic walls and ceilings, the wireless interconnection from a single room to rooms and building floors.

A preferred embodiment uses infrared (IR) lightwaves within each room of a building which permits simpler and less expensive designs than microwave and millimeter-wave embodiments, and such design avoids regulatory restraints by governments. Relay sections are equipped with IR transmitters, receivers and narrow beam width antennas. Manual beam alignment is aided by a visible light beam of equal beam width and direction. Rotational freedom of the antenna system provides precise aiming.

Brief Description of Drawings

FIG.1 is a typical office floor plan with transponders attached to ceiling or attached to floor stands. The dashed line represents the invisible IR network data link.

FIG.2 is a transponder for attachment to a ceiling or a floor stand with protective cover for the unused a.c. power terminals or socket. Two IR network data relay sections are mounted for a 90 degree directional change of the IR beams.

FIG.3 is a transponder for placement on a wall. A structure coupler is mounted behind the transponder sections and is in contact with the wall for pick up of RF signals from the opposite side of the wall.

FIG.4 is a hanging transponder for ceilings with line-of-sight obstructions.

FIG.5 is a detailed view of a relay section with a swivel eye for manual antenna alignment.

FIG.6 is the block diagram of a pair of relay sections connected as a complete data relay station.

FIG.7 is the block diagram of two structure couplers with a room dividing wall shown in center.

FIG.8 is a pair of structure couplers with exposed radio antennas for communication through a wall.

Detailed Description of the Preferred Embodiments

Before describing in detail the particular improvements over U.S. Pat.4,975,926 with the present invention, it should be understood that the present invention resides in a novel transponder to transponder wireless communication link for any indoor network which employes conventional, electrical radio frequency (RF), and optical communication circuits and components or techniques as explained in detail in U.S. Pat.4,975,926. Accordingly, the structure, arrangement and operation of these known techniques, circuits and components have been illustrated here only in simplified drawings and block diagrams, however, specific details that are pertinent to the present invention are shown and explained in sufficient detail to be readily understandable to those skilled in the art.

In accordance with the present invention, the wireless indoor transponder data relay system shown in FIG.1 illustrates the preferred embodiment. For the demonstration of the concept an office floor plan with a small, three room LAN is shown. The inbound and outbound signal cables interconnecting the transponders of U.S. Pat.4,975,926 are by this invention replaced with IR light beams 1. A computer 2 is serving the LAN, all workstations 4 and laser printers 5. A wall mounted relay section 7 translates the hard-wire signal con-

nection from the computer 2 to an inbound and outbound data link by IR beams 1. Transponders 6, shown also in FIG.2, are equipped with two relay sections 7 containing two IR transmitter/receiver pairs. Each relay section 7, shown as FIG.5, contains one receiver with antenna system 8 and one transmitter with antenna system 9. The transponder in FIG.4 has a different mounting provision, which is designed for locations where obstruction by ceiling ducts or other objects would interrupt the light beams normally located directly under the ceiling. The transponder version of FIG.2 is a plug-in unit with a.c. power connection by power connector 10 or Edison socket 11. The unused power connection is protected by cover 12 In FIG.1 two transponders 6 are attached with their Edison sockets to two floor stands 3, while the remaining transponders 6 are plugged into ceiling mounted a.c. power outlets. The preferred transponder embodiment has a mounting plate 13 carrying eight (8) upper sections. Typically, two blank section panels 14 are replaced with two relay sections 7. FIG.2 depicts an effective 90 degree turn of the IR beams by mounting the second section 7 at the third mounting position from the first relay section 7. Common is the "straight through" configuration with two relay sections 7 separated by 180 degrees, as shown in FIG.4. This transponder configuration permits the removal of a transponder for maintenance, as shown in FIG.1, with only the empty power outlet 15 left on the ceiling. Structure couplers 16 bridge the missing transponder with their IR beams 1. Service interruption will only occur in the center room and not in the adjacent rooms.

If transponders cannot be placed on ceilings or walls, floor stands 3 are used. The swivel eye assembly 38 contains the receiver antenna assembly 8, the transmitter antenna assembly 9 and the alignment light 28 with reflector 17. The receiver antenna assembly 8 carries a hood 22 to prevent direct ambient light to enter, a lens 24 with IR detector 25 and an input optical bandpass filter 23 for room light rejection and selection of the link specific wavelength. The transmitter antenna assembly 9 contains a light emitting diode (LED) with lens for transmission of a narrow modulated IR light beam to the next relay section 7. The swivel eye assembly 38 provides 23 degrees of freedom in any forward direction for alignment of the IR beam 1 to the adjacent transponder 6 or structure coupler pair 16. Alignment is aided by the alignment spot light 17 in projecting a visible light spot equivalent to the beam pattern of emitter assembly 9. On-Off control for the spot light bulb 28 is provided by switch 19.

Downlink transponder sections 18 provide inbound and outbound LAN connections to the workstations on the floor. Details of 18 are in U.S. Pat. 4,975,926.

FIG.6 is the block diagram of the transponder relay system. Two relay sections 7 are interconnected by interface connectors 39a and cables 39b, as shown. The upper interface carries the inbound signal and the lower interface carries the outbound LAN signal. IR receiver 20 and IR transmitter 21 can be, in their simplest configuration, amplifiers. The preferred embodiment of the receiver antenna system 8 is comprised of a hood 22 serving as mounting tube for the IR filter 23, lens 24 and detector 25. The detector 25 can be a photo diode, a photo transistor, a photo multiplier tube, etc. The lens can be implemented by a reflector or a more complex, multi-element optical system. When designed as a microwave antenna system, typically required will be a microwave lens or reflector, a low noise preamplifier, a frequency down converter and a diode detector.

The emitter assembly 9 can be a light emitting diode (LED), a laser diode, a conventional laser, or a microwave transmitter with antenna. The preferred embodiment shows a LED with a lens as part of its protective encapsulation.

The inbound and outbound downlink signal interface to the downlink transponder sections 18 are provided by connectors 26. A power supply 27 provides power to the transmit/receive electronics and the incandescent lamp 28 of the alignment spot light 17.

A pair of relay sections 7, as shown in FIG.6, may be used for guiding the signals around obstructions by two cables 39b or by placing the cables through holes in walls or ceilings. In many cases this may not be possible or desireable. As part of this invention the cables 39b, normally located between the relay sections 7, are removed and replaced with two radio couplers 30, as shown in FIG.7. The radio couplers 30 are separated by the width of the wall 31, ceiling or other structure. Each coupler contains a coupling transmitter 32 with carrier generator, modulator and other commonly used circuits for retransmission of the inbound or outbound signals present at the IR receiver 20 output, which are the recovered and amplified signals from the antenna systems 8. The coupling receiver 33 of each radio coupler 30 receives the RF transmission from the coupling transmitter 32 of the inbound or outbound link and is located on the other side of the wall in juxtaposition. The coupling receivers 33 amplify, demodulate the RF signals and recover the digital data by any of the well known radio communication circuits from the RF signal originally transmitted by transmitters 32 on the opposite side of the structure (wall 31). In the preferred embodiment the recovered data is retransmitted with IR by emitter 9 from the relay sections 7 via interface connectors 39a.

The coupling receiver antennas 34 and coupling transmitter antennas 35 may be designed in many configurations and are highly frequency dependent. In the preferred embodiment, as shown in FIG.8, a horn antenna and a microstrip patch antenna are used with close approximation to the wall for maximum near-field RF coupling. The receiver antenna 34 is dual-polarized to reduce losses caused by reflections in the wall structure and has a large aperture for RF wall scatterings. For penetration of the structure, and to minimize RF leakage to the outside, a high-gain, small aperture transmitter antenna 35 is used. The radio coupler 30 is tightly RF radiation sealed and has RF gaskets 36 between the wall (not shown in FIG.8) and the coupler housing for prevention of RF leakage and to minimize RF wall emissions by scattering. The wall transponder in FIG.3 is combined with a radio coupler 30. Two wall transponders of this type, mounted on opposite sides of a wall, provide wireless room to room LAN inbound/outbound connections and provide broadcast transmissions to workstations on both sides of a dividing wall.

It is to be understood that the above-described embodiments are simply illustrative of the principles of the invention. Various other modifications and changes may be made by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof. For example, as shown in FIG.3, the wall transponder equipped with downlink transponder sections 18 for IR wireless broadcast to workstations and equipped with a structure coupler 30, can be modified by replacement of all downlink transponder sections with one omnidirectional RF antenna as a means for downlink transmission to workstations with RF instead of IR, thereby, avoiding the need for higher RF transmitter power on the opposite side of the wall or ceiling.

Claims

1. An indoor wireless communication system to relay local area network (LAN) information from one relay station to another relay station by means of narrow beam electromagnetic radiation serving a plurality of transponders by a plurality of relay stations, each comprising:

   at least one receiving means for receiving a modulated signal representative of the received inbound digital data;

   at least one transmitting menas for transmitting a modulated signal representative of the said received inbound digital data.

2. An indoor signal relay system according to claim 1 wherein at least one second receiving means and at least one second transmitting means has been added to each relay section for multiple link communication by the LAN, comprising:

   of at least one receiving means for receiving a modulated signal representative of the received outbound digital data;

   of at least one transmitting means for transmitting a modulated signal representative of the said received outbound digital data.

3. An indoor wirless signal relay system according to claim 1 or 2,

   wherein coarse aiming of at least one said inbound receiving means together with at least one said outbound transmitting means are simultaneously positioned by a mounting means; and

   wherein coarse aiming of at least one said outbound receiving means together with at least one said inbound transmitting means are simultaneously positioned by a mounting means.

4. An indoor wireless signal relay system according to claim 3, wherein

   aiming of at least one said inbound receiving means and aiming of at least one said outbound transmitting means are simultaneously controlled by a beam alignment means; and

   aiming of at least one said outbound receiving means and aiming of at least one said inbound transmitting means are commonly controlled by said beam alignment means.

5. An indoor wireless signal relay system according to claim 3, wherein

   each said beam alignment means is assisted by a spot light means projecting a light pattern of approximately equal or smaller dimensions to that of the said antennas.

6. An indoor wireless signal relay system according to claim 2, wherein

   each inbound link operates at a different frequency; and

   wherein each outbound link operates at a frequency different from any of the inbound link frequencies.

7. An indoor wireless signal coupling relay system wherein for each inbound and outbound signal connectivity through a wall or ceiling is maintained by near-field electromagnetic coupling of low power signal modulated Radio Frequency (RF), comprising:

   an RF coupling inbound transmitter antenna placed in close proximity to a wall or

ceiling for transmission of inbound signal modulated RF to the opposite side of said wall or ceiling and its reception by the RF coupling inbound receiver antenna located on said opposite side of wall or ceiling,

an RF transmitter for operation of said RF coupling inbound transmitter antenna, including:

an RF carrier generating means matching the said RF coupling inbound transmitter antenna,

a modulating means for modulation of an inbound RF carrier with inbound signals which are obtained from at least one inbound receiving means,

an RF coupling outbound receiver antenna which is placed in close proximity to said wall or ceiling for reception of outbound signal modulatad RF carrier transmissions from the opposite side of said wall or ceiling which are transmitted by the said RF coupling outbound transmitter antenna;

an RF receiver for receiving of said outbound signal modulated RF from said RF coupling outbound receiver antenna, including:

a low noise amplifying means for low level RF amplification,

a demodulating means for demodulation of received said outbound signal modulated RF, and

a recovery means for recovery of said outbound signals,

an RF coupling outbound transmitter antenna placed in close proximity to a wall or ceiling for transmission of signal modulated RF to the opposite side of said wall or ceiling and its reception by the RF coupling outbound receiver antenna located on said opposite side of wall or ceiling,

an RF transmitter for operation of said RF coupling outbound transmitter antenna, including:

an RF carrier generating means matching the said RF coupling outbound transmitter antenna;

a modulating means for modulation of an outbound RF carrier with outbound signals which are obtained from at least one outbound receiving means,

an RF coupling inbound receiver antenna which is placed in close proximity to said wall or ceiling for reception of inbound signal modulated RF carrier transmissions from opposite side of said wall or ceiling which are transmitted by the said RF coupling inbound transmitter antenna;

an RF receiver for receiving of said outbound signal modulated RF from said RF coupling inbound receiver antenna including:

a low noise amplifying means for low level RF amplification,

a demodulating means for demodulation of said inbound signal modulated RF, and

a recovery means for recovery of said inbound signals.

8. An indoor wireless signal coupling relay system according to claim 7, wherein the RF carrier detection power by the said RF coupling inbound receiver antenna is indicated by a signalling means, and the RF carrier detection power by the said RF coupling outbound receiver antenna is indicated by a signalling means, comprising:

a threshold means for each detected RF carrier to establish the best coupling proximity of the said RF coupling inbound and outbound transmitter antennas which are placed on opposite sides of said wall or ceiling by sensing the highest RF carrier power levels received,

a signalling means for each detected RF carrier for indication when said highest RF carrier power levels have been detected by the said threshold means for fixing the location of best signal reception for the signal coupling relay system on either side of the wall or ceiling.

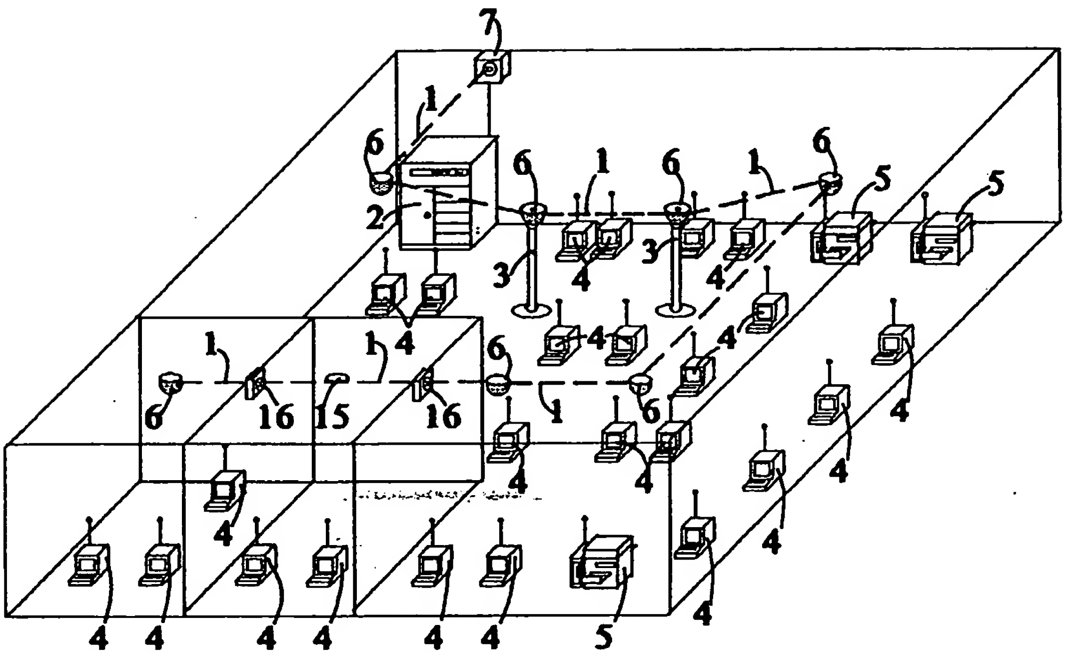

FIG. 1

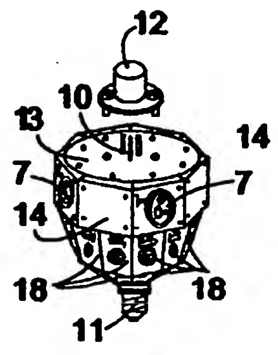

FIG. 2

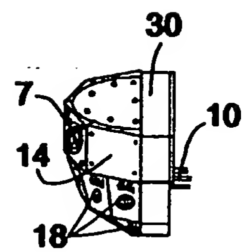

FIG. 3

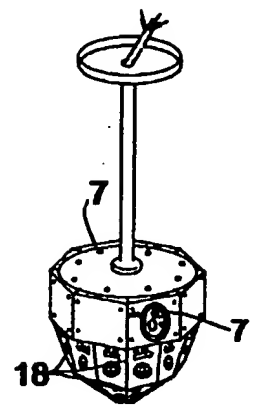

FIG. 4

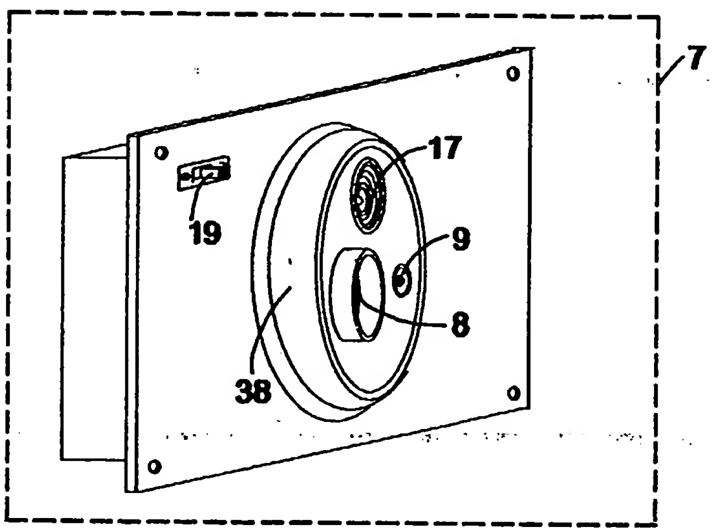

FIG. 5

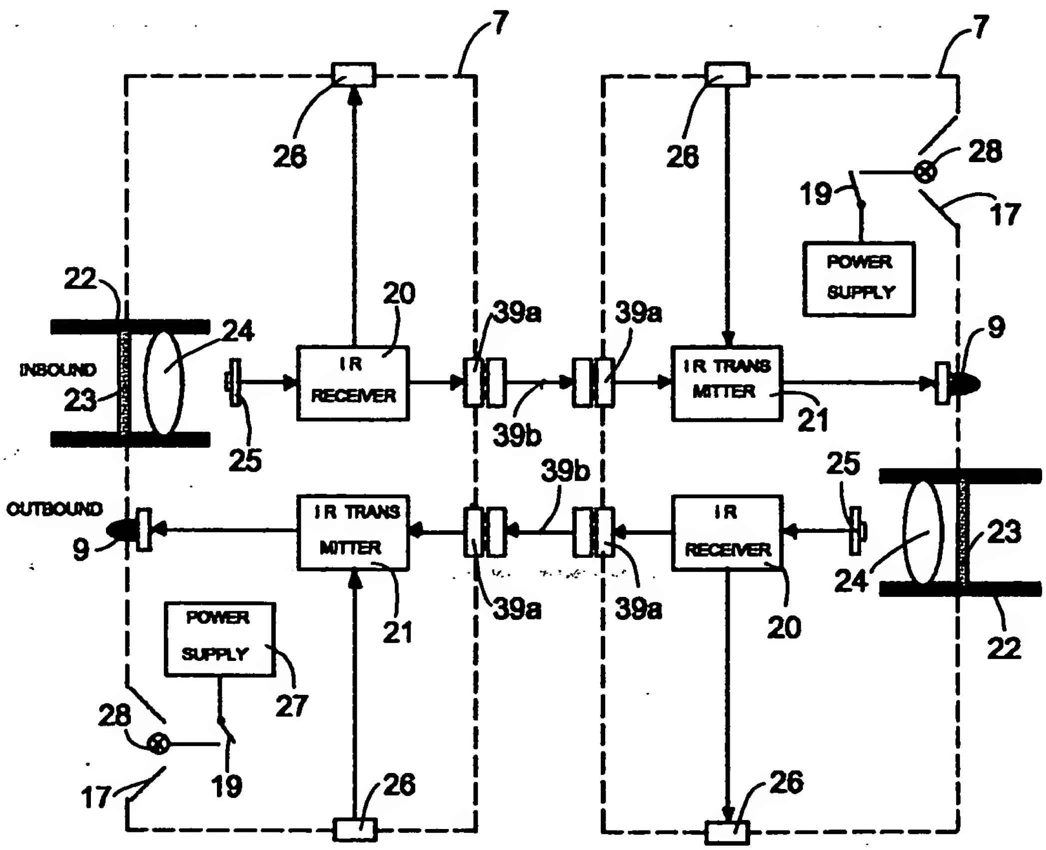
7
7
26
26
28
19
17
POWER SUPPLY
22
20
39a
39a
24
9
INBOUND
I R RECEIVER
I R TRANS MITTER
23
21
39b
25
39b
25
OUTBOUND
I R TRANS MITTER
I R RECEIVER
23
9
24
39a
39a
21
20
22
POWER SUPPLY
27
28
19
17
26
26

FIG. 6

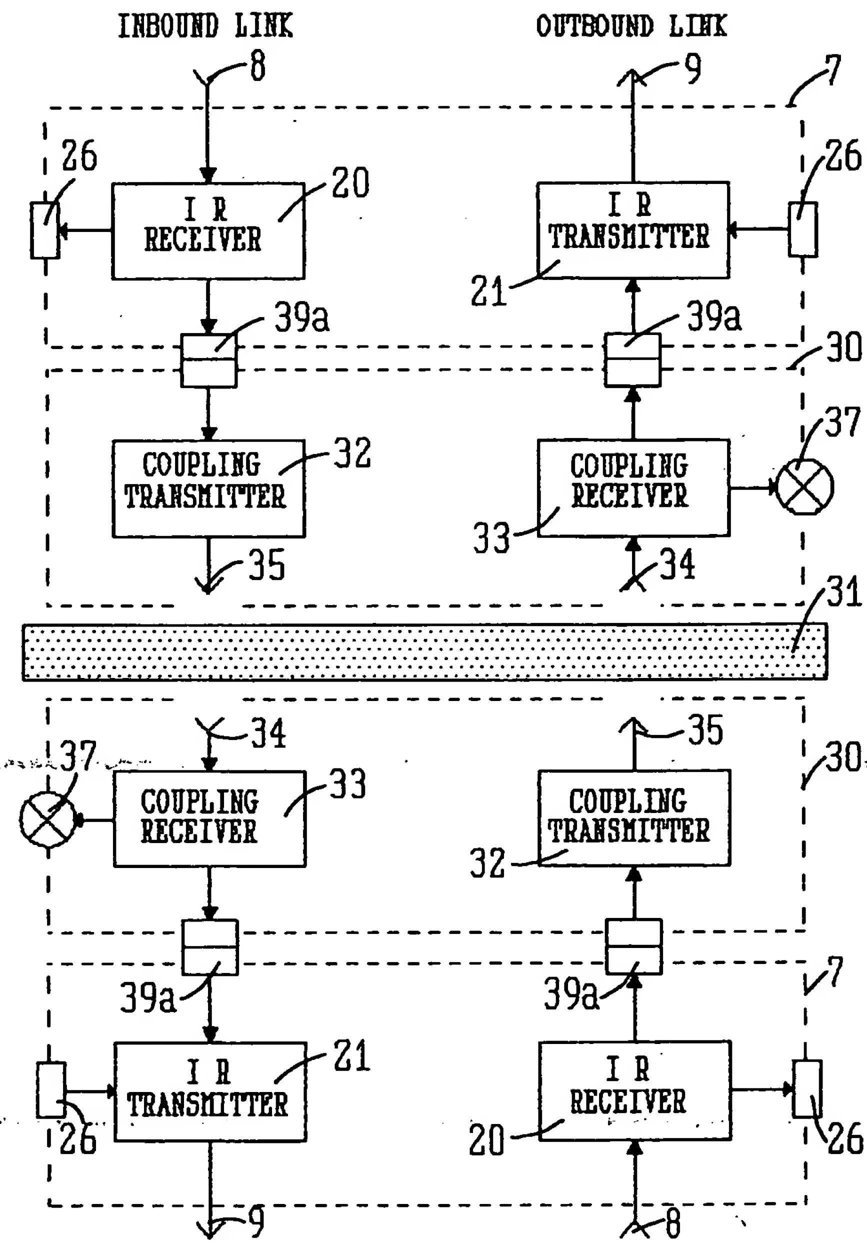
INBOUND LINK
OUTBOUND LINK
8
9
7
26
20
I R RECEIVER
I R TRANSMITTER
26
21
39a
39a
30
37
COUPLING TRANSMITTER
32
COUPLING RECEIVER
33
35
34
31
34
35
37
30
COUPLING RECEIVER
33
COUPLING TRANSMITTER
32
39a
39a
7
I R TRANSMITTER
21
I R RECEIVER
26
20
26
9
8

FIG. 7

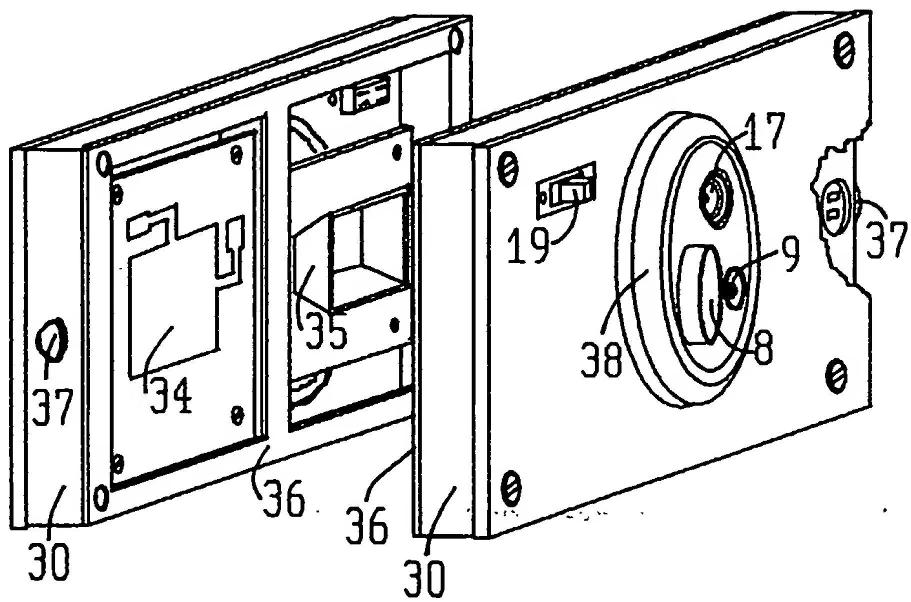

FIG. 8